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Radiation Protection in connection with the Decommissioning of Nuclear Plants

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ABSTRACT:

When a nuclear power plant is dismantled, it is estimated that the volume of low-level radioactive waste that will arise will be as much as during its entire operating lifetime. For obvious reasons, such an extensive task must be planned in advance. Transportation must be organized, necessary interim storage and final disposal facilities must be constructed. The decommissioning work must be carried out in a safe manner so that all of the consideration is shown and all of the measures which are necessary to meet society's requirements are adopted.

This document presents the Swedish Radiation Protection Institute's (SSI's) preliminary views and position concerning the decommissioning of nuclear plants. To prevent the exposure of the decommissioning personnel and the general public to unacceptable levels of radiation and to protect the environment and future generations of human beings, it is SSI's task to formulate and issue the necessary terms and regulations with which the reactor licensees must comply during the decommissioning work. The views and principles presented here are the basis of SSI's continued work on guidelines and regulations for the decommissioning of nuclear plants.

KEY WORDS (chosen by the author):

Clearance, Decommissioning, Environmental aspects, Nuclear plants, Planning, Public protection, Radiation protection, Regulatory aspects, Waste management

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Scope and Purpose

This document presents SSI's position regarding the shutdown of *nuclear plants* in accordance with the definition presented in the *Act (SFS 1984:3) on Nuclear Activities* (English translation). The concept of "nuclear plants" includes ABB Atom's fuel fabrication plant in Västerås, the four nuclear power plants (12 units at four sites), the Studsvik facility outside Nyköping, the Central Interim Storage Facility for Spent Nuclear Fuel (CLAB) at Oskarshamn, the Repository for Radioactive Operational Waste (SFR) at Forsmark, the shutdown heat and power plant at Ågesta, certain facilities at Ranstad as well as several facilities which are currently only at the planning stage (e.g. a future encapsulation plant for spent nuclear fuel).

The *decommissioning of a nuclear plant* refers to the measures which the owner adopts, in one or several stages, to ultimately take the plant out of operation and to fulfil its obligations in accordance with the *Act (SFS 1984:3) on Nuclear Activities, 10 §* and the *Radiation Protection Act (SFS 1988:220), 13§.*

The purpose of this document is to describe what SSI currently considers to be necessary for the decommissioning of nuclear plants to be carried out without harming or subjecting man and the environment to unacceptable radiation risks. This document is a platform for further discussion between SSI and other interested parties as well as a starting point for the work on amending and revising SSI's regulations to ensure that these are applicable and appropriate also with regard to the decommissioning of nuclear plants.

Aim of the Decommissioning Work

The decommissioning of a nuclear plant must be achieved so that man and the environment are protected against unacceptable direct or indirect radiation effects. The burden on future generations must be limited with regard to risk and responsibility as well as expense. The decisions that are made today must not limit, to an unacceptable extent, the possibility of future generations using natural resources. Furthermore, they must not limit the possibility of future generations, without restriction and on their own terms, making decisions regarding their own society and their own future.

The question of the decommissioning of nuclear plants must not be regarded as an isolated phenomenon. The decommissioning and dismantling of a nuclear reactor is a natural part of the activity which, with the help of nuclear fission, converts matter and energy in atomic nuclei into heat and electricity. Energy production using nuclear power plants, nuclear power, includes all stages in the chain from uranium mining, fuel fabrication, waste and nuclear fuel transportation, nuclear power plant operation, decommissioning as well as the handling and final disposal of waste and spent nuclear fuel. An overall approach to energy production is important and can be described through life cycle analysis.

When a nuclear plant is to be decommissioned, this does not necessarily mean that all of the facilities and buildings will be dismantled and removed and that the site will be restored to green field status. It is not possible to reject or accept a particular solution solely on the basis of reasons relating to radiation protection.

In accordance with internationally accepted and respected radiation protection principles and applying a three-step principle (Justification of exposure - Optimization - Protection of the individual), SSI always evaluates new activities involving radiation. The question of justification of exposure in relation to nuclear power was settled at an earlier stage and does not have to be discussed again here.

Optimization means that when a new activity involving radiation is considered to be justified, radiation protection work must be improved until the radiation dose to the personnel and other exposed individuals is so low that the cost of continued improvements is higher than the value of the reduction in terms of the damage represented by the eliminated dose commitment. This assumes that the eliminated collective dose which could have led to cancer cases or hereditary diseases is assigned an economic value, the α value, which is expressed in SEK per mansievert (manSv). Even if a human life is, as a matter of principle, irreplaceable, several situations arise where there is a limitation on the resources that society and individuals can and are prepared to make available in order to save a statistical human life (limitations on air pollution, traffic safety improvements, priorities within the medical services etc.).

SSI has followed the principles specified in a joint publication issued by the Association of Local Authorities, the Federation of County Councils and the National Audit Bureau, *A Better Basis for Decision-making in the Public Sector - A Presentation Model*, Förvaltningsrevisionen informerar, Fi 1991:2, National Audit Bureau, Stockholm 1991 (in Swedish). SSI's board has declared that society must be prepared to pay between MSEK 5 - 25 to eliminate a collective dose which will lead to a statistically calculated cancer case or to other severe late effects of radiation exposure. The reasoning behind this statement is presented *in What Is Protection against Radiation and Other Risks Allowed to Cost?,* SSI-rapport 92-10 (in Swedish). This results in a α value of at least MSEK 0.4 per manSv.

Individual dose limits exist in order to protect individuals so that they do not receive an unacceptably high dose contribution while the collective dose is being optimized. These dose limits are naturally far below the values at which acute effects are manifested.

At present, Sweden applies a dose limit for individuals employed in work involving ionizing radiation at nuclear plants of 20 millisievert (mSv) on average over a five-year period as well as a maximum of 50 mSv during one year. For the public, the dose limit is 1 mSv per year. Since individuals can be exposed to radiation from several different activities (sources) the highest permissible dose contribution from a single activity is often limited to one-tenth of this value (0.1 mSv). For the sake of clarity, it must be emphasized that the dose contribution to members of the general public from natural sources - cosmic radiation at ground- or sea-level, radionuclides naturally found in the body and in the environment, radon in houses etc. - must not be taken into account in this context.

The legislation and the regulations previously issued by SSI have not taken into consideration all stages in the process from the uranium mine to the final decommissioning and disposal of waste and spent nuclear fuel in one and the same context. This report discusses the extent to which SSI's position, policy and ultimately regulations must be supplemented in order to take into account issues which arise in

connection with the decommissioning of nuclear plants within the framework of such an overall perspective.

Legislation

According to the *Radiation Protection Act (SFS 1988:220), 13§,* anyone who conducts or has conducted activities involving radiation shall be responsible for ensuring that the radioactive waste generated by the activity is treated, and when necessary, finally disposed of in a manner that is satisfactory from the standpoint of radiation protection.

According to the *Act (SFS 1984:3) on Nuclear Activities, 10 §,* the holder of a licence to conduct nuclear activities is responsible for ensuring that the necessary measures are adopted for:

- the safe handling and final disposal of nuclear waste generated by the activity or nuclear materials which are not re-used,

- the safe decommissioning and dismantling of facilities where the activity is no longer conducted.

According to the *Act on the Financing of Future Expenses for Spent Nuclear Fuel etc. (SFS 1992:1537),* it is the responsibility of the reactor owners to prepare an estimate of the cost of all of the measures which are necessary for the management of the spent nuclear fuel and the radioactive waste in the reactors as well as for the decommissioning and dismantling of the reactors. The Swedish Nuclear Fuel and Waste Management Co (SKB) prepares this cost estimate on behalf of the owners of the nuclear power utilities. Every year, a cost estimate is submitted to the Swedish Nuclear Power Inspectorate (SKI).

The *Act on the Financing of the Management of Certain Radioactive Waste (SFS 1988:157)* (Studsvik fee), regulates the accumulation of funds for the management of nuclear waste and the decommissioning of nuclear facilities at Studsvik.

The *Radiation Protection Act (SFS 1988:220), 27 §,* stipulates that if a licence has been granted in accordance with the *Act (SFS 1984:3) on Nuclear Activities* or during the period of validity of the licence, the Government or the competent authority designated by the Government may issue additional stipulations which are necessary from the standpoint of radiation protection.

The *Radiation Protection Ordinance (SFS 1988:293), 14 §,* stipulates that SSI must evaluate conditions in accordance with the *Radiation Protection Act (SFS 1988:220), 27 §,* with regard to nuclear activities.

On the basis of the Radiation Protection Ordinance, SSI issues regulations in its regulatory code, SSI FS. This code includes regulations concerning dose limits in connection with activities involving ionizing radiation, regulations for personnel radiation protection at nuclear plants, regulations concerning limitations on the release of radioactive substances from nuclear power plants, etc. Most of the regulations also apply to the decommissioning of nuclear plants. However, a general examination and review of these regulations is necessary and the need for changes which are identified

during such a revision may lead to the issue of new regulations or to the amendment of old regulations.

Factors in the Selection of Decommissioning Alternatives

In order to select a decommissioning method, the licensee must take into account national legislation as well as the rules and regulations which have been issued at a regional and municipal level. Factors and considerations which are involved in the final selection of a decommissioning method or in the implementation of individual stages of the decommissioning may be, for example:

- The requirement to fulfil the obligations stipulated in the *Act (SFS 1984:3) on Nuclear Activities, 10 §* and the *Radiation Protection Act (SFS 1988:220), § 13.*

- The requirements concerning the protection of the environment, both with regard to radiation protection-related and other factors affecting the environment. Environmental targets and national, regional or local environmental protection requirements.

- Precautionary principle. If there is good reason for concern that a certain procedure will entail health hazards or other damage, the procedure should be avoided.

- Principle against the transfer of environmental- and financial responsibilities to future generations.

- The physical, radiation protection- and safety-related status of the plant and how this will change with time including, if necessary, an evaluation of how the integrity of buildings and systems can be maintained during any shutdown periods.

- The possibility of re-using parts of the plant for other activities, i.e. the plant is not fully decommissioned but only as much as required for it to be possible, from the standpoint of radiation protection, to use the site and/or buildings for non-nuclear activities, for example, other types of industrial activity.

- The views and opinions of the general public and the local community. The expected development and use of plants and sites in the immediate vicinity of the nuclear plant. Employment-related reasons and other social factors.

- Waste management and the availability of interim storage and/or final storage facilities for waste, waste management.

- Available transportation capacity and available transportation routes.

- The possibility of authorizing the clearance and re-use of materials and components (backfill, large mechanical devices and machinery etc.). The possibility of depositing inactive materials and materials with very low levels of radiation in normal waste landfills. General regulations concerning such limits are currently lacking and, in the decommissioning projects which have already been carried out, these limits have been established by SSI, from case to case.

- Documentation and preservation of information.

- Planning, financing and implementation of the monitoring and maintenance programmes (ventilation, drainage etc.) which are necessary if the decommissioning is postponed.

- Cost-effectiveness and available funds for the decommissioning. The possibility of guaranteeing funding over long periods of time.

- Whether the plant has been shut down after normal operation or due to the occurrence of an accident or a severe incident.

- Access to personnel with adequate knowledge of the plant and other special knowledge which is necessary for the decommissioning work.

Planning of Decommissioning Work

SSI will promote a dialogue with those who are planning and leading the decommissioning work at as early a stage as possible, so that there can be no doubt about SSI's position and about what should be included in the planning work.

Planning must be carried out already during plant operation. For nuclear plants, a plan for the decommissioning of the plant should be prepared already during operation. If such a plan does not exist, SSI can require that such a plan should be prepared. The extent of detail and the structure and content of such a plan must be such that, on the basis of existing knowledge and experience, it will ensure that the plant can be decommissioned in a way that is compatible with the aim of protecting human health and the environment against the harmful effects of radiation. The plan should also specify how the financial means will be secured to ensure that the decommissioning of the nuclear plant can be carried out after a planned or forced shutdown.

The plan must be updated on a continuous basis so that it specifies the conditions which apply at the plant, the activity at the plant, the inventory of radioactive substances, decommissioning method, financing, the technical implementation of the dismantling work, the protection of the environment etc. If events or accidents occur which may be of importance in the decommissioning work, they should be documented and the decommissioning plan should be modified to the necessary extent.

A final decommissioning plan must be completed no less than one year before a planned shutdown of a nuclear plant is to be carried out. The completed plan must be submitted to SSI as a basis for an application to decommission the nuclear plant. As a minimum, the plant must contain the following information:

1 A description of the aim of the decommissioning project and motivation for the selected decommissioning alternative.

2 The proposed time for the start of decommissioning and a time-schedule.

3 A description of the environment and site where the plant is located as well as a description of the nuclear plant and its previous use. This must contain any normal factors as well as abnormal events during the operation of the plant which can affect the decommissioning work.

4 A description of the organization and an allocation of responsibilities for the decommissioning work. The organization of the transportation of materials should be presented in the plan. The plan must also specify the training that is necessary to ensure that those working on the decommissioning project have the necessary knowledge of the design of the plant, radiation risks, safety regulations etc.

5 A description and a time-schedule for the measures which are necessary for the decommissioning of the plant and the planned use of the area or the plant after the completion of decommissioning work.

6 The results of detailed measurements providing information on:

- Radiation levels and the occurrence of radioactive substances in the plant,

- The concentration of radioactive substances occurring on surfaces, in liquids or in the air,

or in a plant or a part of a plant where such measurements cannot be carried out:

- A best estimate of expected radiation levels and the occurrence of radioactive substances in the plant,

- A best estimate of expected concentrations of radioactive substances on surfaces, in liquids or in the air of the plant.

7 A description of the anticipated quantity of waste which will arise during the decommissioning as well as the way in which this waste is to be sorted, conditioned, measured, stored, shipped as well as the final disposal method.

8 A description of the radiation protection programme to be applied during the decommissioning work.

9 A quality assurance programme for the different stages of the decommissioning project.

10 A detailed description of any measures that must be implemented to ensure that any impact from the activity complies with the regulations and terms. The measurement programme which is to be carried out in the environment and in the plant during the decommissioning work must be described.

11 A description of the measures which will be adopted to limit radiation risks and other risks in the event of accidents. The emergency preparedness organization during the decommissioning work must be described.

12 A radiation dose plan for the different stages of decommissioning work, as well as in total, which shows that the activity has been optimized and that it is within the framework of the regulations and terms issued by SSI.

13 A description of the impact of the decommissioning on the environment, the dose contribution to the public, now and in the future, the impact of the remaining radioactive substances on human health and on future human activities.

14 Other information which the plant owner or the entity that carries out the decommissioning on behalf of the owner considers to be of importance for the protection of human health and for the protection of the environment.

When Is the Operation of a Plant Terminated?

Within the framework of the licence granted by the Government on the basis of the Act on Nuclear Activities, SSI and SKI will stipulate the necessary terms and regulations as well as ensure that the activity is carried out at an acceptable level from the standpoint of radiation protection and safety.

The decommissioning and dismantling of the plant is initiated, in accordance with the definition used in this document, when the demounting of the systems which enables the operation of the plant is started.

Immediately after shutdown, fuel is still stored on site at the nuclear power reactors. Until this fuel is removed, a certain operational competence is required and certain operating procedures are maintained to guarantee safety. Furthermore, control in accordance with the national safeguards system is required. In SSI's opinion, the management of spent nuclear fuel (interim storage, preparations for transportation etc.) which is carried out at the plant after operation is terminated should be seen as a permanent part of the operation of the plant.

Depending on transportation possibilities for the fuel, requirements on storage of the fuel in pools at the reactor before it is taken to CLAB and the operational situation at CLAB, this initial period may be expected to last one or, at most, a few years. SSI considers this period to be shutdown operation in accordance with the nomenclature traditionally used in Sweden.

Measures during Shutdown Operation

In order for optimal use to be made of knowledgeable and well-trained personnel and of available documentation, certain measures should be adopted directly after the shutdown of a plant. Such measures could be, for example:

- Identification of equipment and processes which can be used in the decommissioning work

- Characterization and documentation of the plant's radiological and non-radiological risks

- Removal of spent nuclear fuel and other materials under the control of the safeguards system

- Decontamination of different systems inside the plant

- Handling and removal of operational waste.

Normally, at a nuclear plant, there are personnel whose specialist knowledge can, to a large degree, facilitate the decommissioning work. Their knowledge should be documented, especially if the decommissioning alternative is long term, or if it is anticipated that these individuals will not be part of the decommissioning team. An examination of the available documentation must be carried out to ensure that relevant and already existing photographs, drawings, technical specifications, measurement data on radiation levels and contamination or other documentation of importance for the decommissioning work is utilized.

Long-term Shutdown and Supervision

The plant owner may not wish to dismantle or decommission the plant immediately, and may wish the plant to be shut down, without any measures being taken, for a long or short period of time. Reasons for delaying the decommissioning could be, for example, that a reactor unit has been shut down but that the decommissioning could interrupt operations at a nearby unit or that the construction of SFR-3[1] is not complete. If a severe incident should occur, this could lead to the delay of the decommissioning. It may be necessary to re-evaluate or revise the decommissioning plan. A time period of 1-2 years must be set aside for shutdown operation. The radioactivity and heat must decay to such a level that the fuel can be removed from the reactor and be transported to CLAB for interim storage.

Depending upon the length of the shutdown period, it is necessary to carry out different types of maintenance work, system preservation, inspection and control programmes etc. It may also be desirable to, during this period, carry out certain limited dismantling measures in order to minimize the need for maintenance or to simplify the final decommissioning of the plant.

In SSI's view, such shutdown periods should not exceed a few years. The degradation of systems which are necessary in connection with dismantling, the difficulty of guaranteeing that funds will be available beyond a time frame of several decades, the loss of expert personnel, the environmental debt on future generations are examples of reasons against delaying the decommissioning, in spite of the possible benefit in terms of radiation dose due to the fact that the plant's inventory of radioactive substances will decrease through decay.

If society should wish to more directly determine or should be allowed to determine the time within which the decommissioning or dismantling is to be carried out, this would mean that the reactor owner should be required to make a 'commitment' of some type to adopt, finance and carry out the necessary measures in order to decommission the plant

[1] SFR-3 is the planned section of the waste repository SFR (Slutlager för radioaktivt driftavfall) at Forsmark intended for decommissioning waste

within a particular period of time. However, such a procedure is not within the framework of the current legislation. According to the existing legislation, it is only the responsibility for dismantling and decommissioning the plant which has been established and, in the case of the nuclear power plants and connected facilities as well as the Ranstad, Studsvik and Ågesta facilities, the procedure for financing these activities.

Planning of Radiation Protection Work, Health Physics

Since SSI will probably issue regulations for the decommissioning of nuclear plants, it is appropriate to mention the principles which will apply. The decommissioning work is to be considered as *activity involving ionizing radiation at nuclear plants* and regulations for the limitation of dose, health physics training, medical examinations, instrumentation control, on-site transportation, reporting, documentation and filing of measurement data etc. are, in all essential respects applicable, even during the dismantling phase.

With regard to health physics, the regulations and dose limits issued by SSI in SSI FS 1989:1, 1994:2, 1994:5 are applicable. SSI's limits regarding permissible individual doses for personnel involved in nuclear activities: a maximum annual effective dose[2] of 50 mSv, a maximum accumulated effective dose of 100 mSv for a period of five consecutive years, as well as a lifetime limit on the accumulated effective dose of 700 mSv also applies to the decommissioning of nuclear plants. SSI's requirement on the application of the ALARA principle will lead to considerably lower average doses to the employees than these dose limits.

According to SSI FS 1994:2, 12 §, activities during the operation of a plant should be planned so that the average value of the collective dose for five consecutive calendar years does not exceed 2 manSv per gigawatt of the installed electrical output. There is no corresponding planning value for the other nuclear plants. During the past 10 years, the collective dose at Studsvik has been in the range of 450 - 750 mmanSv, while the collective dose to the personnel at ABB Atom's fuel fabrication plant in Västerås usually amounts to one-tenth of these values (40 - 60 mmanSv).

Special instructions on how a planning value is to be applied to the decommissioning work will be issued by SSI. At present, an exact value cannot be disclosed. However, one objective might be to state that the total collective dose to the decommissioning personnel must be less than 3 - 4 manSv for the decommissioning of a single unit at a nuclear power plant. With regard to the other nuclear plants (ABB Atom's fuel fabrication plant, the research reactors and the other plants at Studsvik etc.), an estimate will be made in each individual case. However, the licensees of these plants will also be required to ensure that the collective dose to decommissioning personnel is optimized.

A dose budget must be included in the final decommissioning plan. Individual and collective doses are to be estimated for individual, major stages of work as well as for the total decommissioning project. In this context, the importance of experience feedback and documentation to obtain realistic dose estimates cannot be sufficiently

[2] For the sake of simplicity, the effective dose (ICRP 60) is used instead of the effective dose equivalent. The difference, in these contexts, is often negligible.

emphasized. In the case of large projects, such as the steam generator replacement at Ringhals or the renovation work at Oskarshamn 1, important lessons can be learnt which can be applied when making such estimates. However, the knowledge gained from the normal operation of the plants is also valuable.

Radioactive Releases to the Environment, Doses to the Public

The limit value for the effective dose to individual members of the general public is the ICRP's recommended and SSI's adopted value of 1 mSv/year (SSI FS 1989:1; For individual years, the effective dose may increase to up to 5 mSv, if the average value during the person's lifetime is expected to be less than 1 mSv/year).

SSI FS 1991:5, *The Swedish Radiation Protection Institute's Regulations for the Limitation of Releases of Radioactive Substances from Nuclear Power Plants* states that each nuclear power plant must have devices for the containment and retention of radioactive releases. These devices must be designed so that the effective global collective dose, resulting from the operation of the plant, may not exceed 5 manSv per year and gigawatt of installed electrical output (for the Studsvik facility and ABB Atom's fuel fabrication plant, separate regulations exist where a limit of 0.5 manSv is specified). These devices must also be designed so that the whole-body dose or the corresponding sum of the weighted doses in all the organs of the body of a member of the critical group is less than the **reference dose** of 0.1 mSv per year. Each combination of activity release (release of radioactive substances to the air or water) which results in this dose is called a **norm release**. The relationship between a norm release and the resulting radiation dose has been generalized to apply to the average conditions over an entire year.

It is SSI's firm opinion that the decommissioning of a nuclear plant must be carried out so that releases to the water and air recipients are considerably lower than during operation of the plant. Since, during dismantling, it is primarily a question of activity in particulate form, it should be possible to keep the releases at a very low level with suitable filtered ventilation. The same applies to water- and airborne waste. In spite of this, the decommissioning work may comprise the conditioning of waste through the melting of metals, the incineration of waste or other such activities which can be related to the decommissioning or dismantling of a certain nuclear plant and, therefore, certain limited releases will probably always occur.

SSI will draw up special requirements for the calculation and limitation of doses to the public as well as for the protection of the environment in connection with the decommissioning of nuclear plants.

The decommissioning plan which is prepared by the plant owner must describe the impact of the decommissioning activity on the environment, the size of the dose contribution to the public, now as well as in the future, as well as the impact of the remaining radioactive substances on the environment and on the activities of future generations and on human health in the future. This description must be based on the 'normal case' and the degree of uncertainty in the estimates as well as the possible extreme cases which can arise must be specified.

Waste, Repository for Decommissioning Waste

In the plans prepared by the Swedish Nuclear Fuel and Waste Management Co for the construction of SFR-3, i.e. the section of the SFR repository which is intended for decommissioning waste, this section is expected to be taken into operation a couple of years after the year 2010 (see e.g. SKB, Plan 95, Cost of the Radioactive Residual Products of the Nuclear Power Plants, June 1995, in Swedish). CLAB is already in operation. However, it is planned to extend the facility at a later stage. In order to receive the large quantities of waste which arise in connection with the dismantling of nuclear power plants or other large nuclear plants, it is required that suitable waste facilities and repositories should be available.

At present, SSI has no reason to question the plan that SKB has made and merely observes that dismantling (decommissioning) of nuclear plants, can probably not be initiated before a repository is available for the large volumes of low- and medium-level decommissioning waste (SFR-3).

A very important factor in the handling of decommissioning waste is the classification of the waste. It is important to not only measure the activity but to, already from the start, define different waste categories and how to optimize the work.

Some nuclides are difficult to measure and can, therefore, not be measured in a routine manner. The concentration of these nuclides in the waste is therefore determined through knowledge of the origin of the waste, the method used to irradiate the materials and with the help of correlations to radionuclides which it is easier to measure. Several research projects have already been carried out within this area (e.g. *Radionuclides Difficult to Measure in Waste Packages*, 3 November 1995, Brenk Systemplanung, Aachen, Germany). It is SKB's task to verify the nuclide inventory in the waste to be shipped to SFR. Procedures already exist for shipping operational waste to SFR-1.

According to the Ordinance on Nuclear Activities, SFS 1984:14, 19 §, SSI may grant permission for the construction of waste landfills on condition that the total activity level does not exceed 10 TBq, of which no more than 10 GBq may comprise alpha-emitting substances. SSI does not envisage any direct obstacles, at the moment, to the licensing of waste landfills for waste with very low levels of radioactivity at the nuclear plants in connection with the dismantling and decommissioning. However, this question cannot be resolved until several factors have been considered. Radiation protection is only one of these factors. The exact regulations concerning the permissible radioactive inventory, surface dose rates for the waste packages etc. which are to be applied if such landfills are constructed have not been established. However, the principles which are applied at the landfills which are currently used for very low-level operational radioactive waste can so far be considered to provide guidance on this issue.

Clearance of the Site and Plant, General Principles

After the decommissioning is completed and SSI has established that the stipulations of the Radiation Protection Act have been fulfilled, the plant, buildings and site can be granted clearance, i.e. released from the requirements of the Radiation Protection Act. SSI would like to avoid making a total commitment to individual values of radioactivity, since in the long term, this can prevent an optimization of the radiation

protection in an individual case. Depending on the application, it will be possible to accept different clearance levels (normal waste landfill, re-melting and recycling of metals, direct re-use, re-use as backfill etc.).

A general guideline for completely unrestricted use is that surface contamination on soil, in buildings and on large components or large volumes of waste should not exceed 5 kBq/m^2 for beta and gamma emitters as well as 0.5 kBq/m^2, in the case of alpha emitters.

When removing small quantities of operational waste or tools from controlled areas and in connection with the clearance of some limited quantities of materials, SSI applies higher values, 40 kBq/m^2 for beta and gamma emitters as well as 4 kBq/m^2 for alpha emitters.

With regard to specific radioactivity, 500 Bq/kg for beta and gamma emitters and 100 Bq/kg for alpha emitters can be considered to be suitable limits for clearance. These values are also general guidelines. If simple cleaning, decontamination or other optimized measures can be adopted to reduce the level of radioactive substances, this should always be done.

Particular consideration must be taken with regard to material contaminated with long-lived alpha emitters and metals which are intended to be re-used. It is not only the individual doses which must be limited. Collective doses must also be taken into account if materials which have been granted clearance are to circulate in society in their original or conditioned form.

It should be possible to handle radionuclides with less harmful radiation, such as ^{3}H and ^{55}Fe less restrictively. If there is a risk of contamination of large volumes of waste or large sections of buildings by significant amounts of ^{234}U, ^{235}U, ^{241}Am, $^{239/240}$Pu, ^{244}Cm, the material should not be granted clearance as a matter of principle.

Decommissioning after Severe Incidents

If a major fuel failure or severe incident should occur at a nuclear power plant or a nuclear plant, this could have drastic consequences on the decommissioning work. A number of these issues have been investigated in the report *Management of Radioactive Waste from a Major Core Damage in a BWR Power Plant*, J. Elkert et al, Final Report of the NKA Project KAV 390. Nord 1990:31, March 90.

Operating experience from the past ten-year period shows that uranium dissolution in connection with common clad failure can result in the dissolution of significant quantities of fuel. For example, it can be mentioned that during the fuel failures at Oskarshamn 2 during 1988-89, about 400 g of UO_2 was dissolved over an operating period of a few months. There is reason to suspect that, in connection with major fuel failures, it is the dispersion of fuel fragments and the dissolution of fuel which can lead to the worst consequences in terms of radiation protection and, thereby, cost. New calculations of the 'blocked coolant flow' scenario for BWRs, show that if the water flow through a fuel assembly is reduced by more than 90%, the assembly can overheat and melt very rapidly. In the worst case, this could lead to about 150 kg of uranium

being spread throughout the reactor systems (Private communication, Tor Ingemansson, ALARA Engineering AB).

SSI has launched a project[3] to identify the problems associated with transuranic elements and to estimate the need for extra work in connection with the dismantling of a nuclear power plant where extensive fuel failure has occurred with fuel dissolution as a result.

[3] This project is now completed: SSI Project P930.96, *Transuranium contamination in BWRs after fuel accidents and its impact on decommissioning exposures and costs,* Report 96-0085R, December 1996

SSI-rapporter

97:01 Utvärdering av radonavskiljare -
-Effekt på radon i dricksvatten från bergborrade brunnar
Anders Lindén *100 kr*

97:02 Mätningar av 137 Cs och 90 Sr i konsumtionsmjölk mellan 1991 och 1996
Miljöövervakning och Mätning *40 kr*

97:03 Radiation Protection in connection with the Decommissioning of Nuclear Plants
Div. of Occupational and Medical Exposure. Div. of Waste Management and Environmental Protection *40 kr*

SSI Rapport

STATENS STRÅLSKYDDSINSTITUT, SSI, är en central tillsynsmyndighet med uppgift att skydda människor, djur och miljö mot skadlig verkan av strålning. SSI arbetar för en god avvägning mellan risk och nytta med strålning, och för att öka kunskaperna om strålning, så att individens risk begränsas.

SSI sätter gränser för stråldoser till allmänheten och till dem som arbetar med strålning, utfärdar föreskrifter och kontrollerar att de efterlevs, bland annat genom inspektioner. Myndigheten informerar, utbildar och ger råd för att öka kunskaperna om strålning. SSI bedriver också egen forskning och stöder forskning vid universitet och högskolor.

Myndigheten medverkar i det internationella strålskyddssamarbetet. Genom projekt Strålskydd Öst bidrar SSI till förbättringar av strålskyddet i främst Baltikum och Ryssland. SSI håller beredskap dygnet runt mot olyckor med strålning. En tidig varning om olyckor fås genom svenska och utländska mätstationer och genom internationella varnings- och informationssystem.

SSI har idag ca 125 anställda och är beläget i Stockholm.

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